An Independent Evaluation of the Earplug as a Treatment for Speech Comprehension Difficulties in Selected Children

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Researcher and Writer: Betty Schoenhofer

Advisory Team: Leigh Hill, Education Response Centre
Henry Janzen, University of Alberta
Frank Josey, St. Albert School District No. 3

Editorial Team: Patricia Cox
Alexandra Hildebrandt

Desktop Publishing: Patricia Cox
Sandra Mukai

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Introduction

Research by Dr. Paul Green has suggested that some children with learning difficulties, but who are of average intelligence and with no hearing impairment, show an advantage in comprehending speech when it is presented via headphones to one ear alone (monaural), as opposed to listening with both ears together (binaural). The effect is measured by asking the child to recall each of thirty stories from the Auditory Comprehension Test (ACT) immediately after hearing each story. Ten stories are presented in each of the following conditions: left ear only, right ear only, or both ears together (binaural). It is claimed by Dr. Green, furthermore, that children showing a significant advantage of monaural versus binaural speech comprehension, as measured by the ACT, benefit from improved speech comprehension if an earplug is worn in the poorer scoring ear. When testing has shown a monaural advantage, many children have been prescribed earplugs for daily use by physicians on recommendation from Dr. Green (Green & Josey, 1989).

The present study was designed to evaluate the validity of the earplug treatment independently of the original researcher through independent testing and analysis of data collected through interviews. Children originally tested by Green were selected by the research team and retested by an impartial researcher, blind to original test results. Children's responses were tape recorded and Green scored the responses of each child blind to the researcher's own ratings. Thus, independent retesting allowed for evaluation of the following:

- the reproducibility of the monaural advantage;
- the reliability of the monaural advantage over a mean period of two years from original testing by Green to retesting by the independent researcher; and
- the inter-rater reliability of scores from the ACT.

The results support the validity of a monaural effect in that the retest group, as a whole, showed a mean advantage of approximately 30% in recalling stories in one ear as opposed to both ears together. Inter-rater reliability was found to be very high. Forty-five per cent of children who were prescribed the earplug, continued to wear the earplug on a daily basis at follow-up. Parents,' teachers,' and childrens' reports at interviews conformed with reports of the effects of an earplug described in interviews with independent professionals who have also prescribed earplugs. The earplug was reported as producing improved abilities to attend to and comprehend speech in 45% of the samples.

Limitations to the study include the fact that longitudinal measures of actual school performance were not undertaken and objective data on academic performance are incomplete. Some individual children did not show significant advantages of monaural speech comprehension at retest, which represents an unexplained lack of stability of the effect in a minority of cases. The earplug does seem to have beneficial effects in improving speech comprehension in many cases. Further research is needed to evaluate more fully the actual effects of an earplug on other measures of performance, including achievement tests, other speech discrimination and language tests, intelligence measures, and behavior.

Literature Review

Although using an earplug to improve understanding of speech appears to be a simplistic therapy, explanations of its theoretical basis are not. Earplug candidates do not have hearing loss; the cause of their impairment is hypothesized to be an abnormality in the mechanism of the brain which enables understanding of language. The complexity and breadth of this subject precludes an extensive review of relevant literature for the purpose of this document; therefore, it will be limited to a discussion of theories which constitute current understanding of brain function, an examination of listening tests used to assess hemispheric activity, and a summary of reports which describe effects associated with earplug wearing.

Given the equivocal nature of research findings in respect to language processing, it must be acknowledged that current theories and assumptions which attempt to explain cerebral function during this process are largely speculative. Two theories, however, appear to constitute the basis for current investigation and are partially supported in the literature.

One theory, (Kimura, 1961a; 1961b; 1967), develops an explanation based on the anatomy and physiology of the brain and auditory structures. In this theory, the brain is considered to be lateralized, with stronger connections existing between the ear and the hemisphere opposite than between the ear and the hemisphere on the same side. Processing of verbal stimuli is believed to be normally within the dominant (usually left) hemisphere, necessitating transfer across the corpus callosum of verbal input received by the nondominant hemisphere (usually right). Numerous subsequent studies, summarized in Hugdahl (1988), have confirmed the role of the left hemisphere in processing verbal stimuli and of the right nonverbal stimuli; however, normal and efficient processing of language appears to be dependent upon an interrelationship of areas within both hemispheres of the brain (Geffen, 1980; Schneiderman & Saddy, 1988; Joanette, Goulet, & Le Dorze, 1988; Shipley-Brown, Dingwall, Berlin, Yeni-Komishan, & Gordon-Salant, 1988). How this occurs is not presently understood.

An alternative theory, proposed by Kinsbourne (1970), uses attentional mechanisms to explain asymmetry of brain function. This theory proposes that expectation of verbal auditory stimuli causes activation of the left hemisphere. In this theory, variables such as selective attention and planning are considered to be important factors governing the efficiency of the system. The relationship between attention and language processing in adults is the focus of considerable current research, with some evidence that the left hemisphere is more specialized for selective attention and the right

hemisphere for divided attention (Geffen, 1988; Wale & Geffen, 1986; 1989). The contribution of attentional abnormalities to learning problems is being investigated in samples of reading disabled children. Results suggest attentional instability causing inappropriate activation of the hemispheres during auditory processing (Obrzut, Conrad, & Boliek, 1989; Smith & Griffiths, 1987) or limited capacity to attend (Dickstein & Tallal, 1987).

During the past thirty years, dichotic and monaural listening tests have been used extensively as noninvasive measures of cerebral functioning.

Dichotic listening tests, the most commonly used instruments to measure auditory cerebral function, are composed of two competing messages presented simultaneously, one to each ear, through headphones. A variety of verbal and nonverbal stimuli are used: series of numbers, syllables, words, musical passages, or environmental sounds. The subject is asked to report what was heard. While the mechanism causing ear differences can not be conclusively described, a right ear advantage (REA) implying left hemisphere activation, is normally found for verbal material and a left ear advantage (LEA) for nonverbal material. Dichotic tests have repeatedly found ear differences in normal adults and children of various ages, and in subjects with known cerebral dysfunction. While dichotic tests appear to be sensitive detectors of ear differences, a number of factors have been identified which can influence test reliability, including strategies the subjects choose to employ when reporting (Mohr, 1987), the type of stimulus presented (Wexler & Halwes, 1985), and whether the subject is directed to listen with either or both ears (Obrzut, Boliek, & Obrzut, 1986; Obrzut, Conrad, & Boliek, 1989).

Monaural testing differs from dichotic testing in that a stimulus such as nonsense syllables, words or series of numbers is presented to one ear only, rather than to both ears simultaneously. While it is less popular than dichotic testing and apparently less sensitive to the detection of ear differences in normal populations, ear differences have been reported in numerous experiments using monaural tests (Henry, 1983). The ACT is a monaural test, however, it differs from others in two significant respects: it uses recall of passages which contain complex speech similar to that encountered in daily life; secondly, it compares monaural (one ear) with binaural (both ears) performance. The only references in the literature documenting this comparison and offering hypotheses about its cause are those of Green and his associates (Green 1984; 1987; Green, Hallett & Hunter, 1983; Hallett, Quinn & Hewitt, 1986). The cause of a monaural advantage has been hypothesized by Green to be abnormality in structure of the corpus callosum (Green, 1984). In a recent paper (Green & Josey, 1989), the cause has also

been linked to control of the blood flow in the brain, possibly by the basal ganglia. Abnormalities were found, using Positron Emission Tomography, in the cerebral blood flow of an adult who has displayed a monaural advantage on repeated testing.

Documentation of the use of an earplug to enhance speech comprehension was not found in an extensive review of the medical, psychological, audiological, and educational literature other than the report of Green (1987). Earplugs have, however, been reported to reduce or eliminate hallucinations in psychiatric populations (Howells & Rice, 1990; Birchwood, 1986; Done, Frith, & Owens, 1986; James, 1983). These results require cautious interpretation since the effect on the hallucinations was not necessarily contingent upon plugging the "poor ear" and was not effective for all subjects. They do suggest, however, that an earplug may produce a physiological change which impacts on cerebral functioning in some manner which is unexplainable at this time.

To summarize, there is a general consensus in the literature that the two hemispheres of the brain are functionally specialized, with the left hemisphere normally activated for processing verbal input, and the right hemisphere for nonverbal input. Current understanding of the brain's activation is rudimentary; however, there is some evidence that normal processing of language is dependent upon an interrelationship between both hemispheres and that attentional and other factors impact upon this process. Monaural and dichotic listening tests are commonly used to study activation of the hemispheres through detection of ear differences. While dichotic tests are more sensitive to ear differences in normal populations, both types of tests have identified ear differences in abnormal populations. The ACT, a monaural test, differs significantly from others in that passages similar to natural speech are used, and the test compares monaural with binaural performance rather than right versus left ear performance. Other than Green (1987), no evidence was found in the literature documenting the use of an earplug to improve understanding of speech; however, its effect in reducing or eliminating hallucinations suggests that it may have some physiological effect which cannot yet be explained.

Background to the Present Independent Evaluation of the Earplug Phenomenon

The rationale for the therapeutic use of an earplug is based on the concept of monaural advantage, an effect which appears to result in improved comprehension of speech, when listening with one ear rather than both. The cause of this effect was originally hypothesized by Green to be interference between the two hemispheres of the brain (binaural interference), following experiments conducted with adult schizophrenics in 1973. In these experiments it was found that after identifying a hidden shape with one hand the patients were unable to identify an identical shape with the other. The inability to discriminate appeared to be consistent for simple and complex tasks in schizophrenic patients but was not observed in normal individuals. On the basis of these observations, Green hypothesized that in the schizophrenic group, transfer of learned manual discriminations was being impaired by interference occurring between the two hemispheres of the brain (Green, 1978).

Subsequently, Green studied the phenomenon of interference in respect to auditory function, using various tests, eventually resulting in the development of the ACT (Green & Kramar, 1983). This test, used to assess hemispheric functioning during language processing, is composed of five sets of stories (30 in total) of gradually increasing length and complexity, similar in format to news reports. Using headphones, stories of equivalent difficulty are played to each ear individually and to both simultaneously. After listening to each story, the client is requested to recall as much as possible of what was heard. Scoring is based on the accuracy and extent of recall. Following completion of the test, the following scores are calculated:

- *Left ear score* - total scores for recall of stories played to the left ear.
- *Right ear score* - total scores for recall of stories played to the right ear.
- *Binaural score* - total scores for recall of stories played to both ears simultaneously.

Using the three scores obtained from the test, the presence of a monaural advantage can be determined by calculating the following values and comparing the result with cutoff scores, which are suggested by Green to indicate a statistically abnormal performance:

- *Mean score* - the average of left (L), right (R), and binaural (B) scores (L+R+B/3); suggested cutoff score ≤80.
- *Absolute ear difference* - right ear score minus left ear score (R-L); suggested cutoff score ≥16.
- *Monaural advantage* - Highest single ear score (HM) minus the binaural (B) score (HM-B); suggested cutoff score ≥17.
- *Percentage monaural advantage* - (HM-B)/Bx100; suggested cutoff ≥20%.
- *Percentage Ear Differences* - (R-L)/(R+L)x100; suggested cutoff ≥10%.

In the course of his research using the ACT, Green has found that auditory comprehension in normal subjects is slightly better when listening with both ears, but that listening with either ear or both is relatively equivalent. In some individuals, however, comprehension of speech has been measurably greater when listening with only one ear. The prescribed treatment for these cases is the use of a therapeutic earplug for the "poor" ear.

Right ear advantage, implying left hemispheric dominance for language processing, appears to be well accepted, being a commonly reported finding during dichotic testing with normal subjects. Some monaural procedures reveal a similar right ear advantage (Henry, 1983). However, the ACT does not reveal any such advantage in normal individuals and, hence, the test departs from the tradition of dichotic listening tests, not only in its structure but also in its empirical results with normal subjects.

The notion of an abnormal monaural advantage for speech and treatment using an earplug remains controversial. Two factors contribute to this situation: the results are unexpected and an extensive search of the literature has failed to reveal studies of monaural versus binaural speech comprehension apart from those of Green and replication studies of his original work. When Green and Kotenko (1980) published their report of abnormal monaural advantage over binaural comprehension, there were no studies which provided information on the relative performance of listening with one ear versus two ears in speech comprehension.

Since comparisons between the performance of listening with one ear with the performance of listening with both ears together would seem to be a control feature in any study employing monaural stimuli, it is surprising that this comparison has not been reported. Thus, Green's results represent a venture into a previously unexplored domain, and at this time constitute the vast majority of published work in this area.

While his initial research was conducted with adults, since 1983 Green and others have investigated the phenomenon of monaural advantage in children of schizophrenics, and in normal and learning disabled children. Investigations of children tested with the ACT in St. Albert and Edmonton have identified a monaural advantage in samples of learning disabled children but not in normal children (Green & Josey, 1989). In Britain, a monaural advantage was identified in two studies of children of schizophrenics (Hallett and Green, 1983; Hallett, Quinn, & Hewitt, 1986).

Since 1984, 46 children from St. Albert School District No. 3 have been assessed using the ACT and found to have a monaural advantage. Of this group, 43 have had earplugs fitted with the approval and supervision of a physician. In 1987, a survey of "earplug cases," implemented through the office of the Director of Student Services, was presented to the Board of Trustees. Parental responses to questionnaires and checklists, and anecdotal reports from teachers and students described behavioral improvements in the majority of students wearing the earplugs. Of sixteen cases reported, ten were described as improving academically and/or in behavior; two demonstrated worse behavior; and one demonstrated no change. Three students who refused to wear an earplug showed neither academic nor behavioral change (St. Albert School District No. 3, 1987).

In addition to the St. Albert survey, anecdotal reports documenting behavioral change associated with earplug wearing, have been made available to Green by parents, patients, and other professionals who have used the test and recommended earplugs. An illustrative sample of reports follows.

Anecdotal information concerning four specific cases was provided to the writer by professionals who have used the ACT.

Case 1

The mother reported that this female child received an earplug in Grade 4. According to the mother, effects observed by herself and the child's teachers, were an improved ability to understand directions and improved school achievement.

Case 2

The mother reported that this male child received an earplug in Grade 8, resulting in improved understanding of verbal information, more appropriate verbal responses, less hesitation before replying, improved school achievement, and improved behavior at home. No teacher report was available to support the parent's observations; however, the child apparently believed that the earplug helped.

Case 3

A report from a school principal described a male student who received an earplug in Grade 8. The student, prior to receiving the earplug, was described as passive, undirected, shy, and "in another world." Poor short-term memory, a lack of concentration, and academic achievement averaging 40% were cited as typical. The student moved to another school following receipt of the earplug. In an informal follow-up conducted by the principal, the mother reported that the child was wearing the earplug consistently and that academic achievement had improved to an average of 70%.

Case 4

This student received an earplug in Grade 8. The school principal described the child as having poor short-term memory and below average academic achievement. Teacher reports described this child as being more outgoing, responsive, and happy when wearing an earplug. The principal reported a significant improvement in academic performance.

Several reports were made available to the writer by Green:

Case 5

In an unsolicited report received from a parent of a nine-year-old boy, the child was described as willing to wear the earplug, less bothered by noise, less tearful, and more confident. Mean achievement on the administration of the Canadian Achievement Test prior to receiving the earplug was at the 41 percentile; in the administration following receipt of the earplug, achievement was at the 59 percentile. As an experiment, the child wore an earplug in his left ear for a short time; regression to the previous "pre-earplug" behavior occurred. Resumption of wearing a right earplug resulted in reappearance of the initial, positive effects. In a follow-up of this child as part of this study, it was determined that he continued to wear the earplug, has maintained academic achievement generally at the 59 percentile, and has continued to exhibit improved behavior.

Case 6

During a videotaped interview, an adult female diagnosed as manic-depressive, reported that auditory hallucinations stop when she wears an earplug, even when unmedicated. Other behavioral changes reported were a more stable mood, less depression and confusion, and less tendency to interpret hostility from others.

Case 7

On testing with the ACT, a boy with a left temporal lobe cyst was found to have normal recall of stories played to the left ear (55 percentile), but impaired recall of stories played to both ears (three percentile). In a videotaped interview with the mother and child, his problems were described as forgetting or misinterpreting when spoken to. Both the mother and child reported that memory and accuracy of recall of speech improved with earplug wearing, and that these changes had been observed by the child's classroom teacher as well as the parent.

A number of individuals have reported beneficial effects which have been associated with earplug wearing, for example: better understanding of speech; greater alertness; and improved academic achievement. Unfortunately, objective evidence of change is limited and varies from case to case. The influence of variables such as school or program changes, modifications in expectations of the individual, or the influence of wearing an earplug on the self-perception of the wearer can not be defined. Despite the limitations which are implicit in anecdotal reports, it is noteworthy that numerous positive effects associated with earplug wearing are reported, that some similarity of effects exists across these cases, and that the effects are reported as continuing over time. While these positive reports are intriguing, the intent of this study is to consider both objective and subjective evidence to assess potential benefits and liabilities associated with earplug wearing.

This study had three major goals:

Independent testing of the monaural advantage

It was intended to establish whether or not it was possible to replicate the basic effect claimed by Green, which is that in a core group of "earplug cases," one ear would show significantly greater speech comprehension than two ears together on the ACT. After intervals of up to five years, children originally tested by Green and recommended for an earplug were retested by an independent impartial examiner. In this group, failure of retesting to find a significant advantage in speech comprehension in one ear alone versus two ears together would present a fundamental challenge to the earplug method and bring into question the empirical validity of the reported monaural advantage. Failure to replicate Green's findings would suggest either that the monaural advantage was not reproducible independently or that it was not reliable over the period of time during which retesting was performed. In either case, this would seriously damage the basic rationale for the use of an earplug as a treatment method. On the other hand, a positive replication would add support to the validity of the monaural advantage, which underlies the earplug treatment (Green & Josey, 1989).

Evaluation of the effects of earplug wearing by children

Should independent retesting support the existence of the abnormal monaural advantage in some children, it would then be important to investigate the efficacy of an earplug worn daily as a treatment in selected children with speech comprehension deficits. The second major goal of this study was to evaluate whether the children advised to wear an earplug had actually worn one and, if so, whether wearing the earplug had led to any beneficial changes, especially in terms of improving the ability to pay attention to and comprehend speech in real life. Interviewing parents, the children, and their teachers would establish whether or not the earplug had been worn and whether there were effects which might be associated with earplug wearing.

Assessing the "usability," validity, and reliability of the ACT

Interviews with psychologists, audiologists, and speech pathologists who have used the ACT as a measure of speech comprehension in children would provide professional feedback as to the value of the test as a practical measure of speech comprehension difficulties. Collating data, obtained by these professionals experienced in test administration and in the use of the ACT, would also provide some objective evidence with regard to the presence or absence of the monaural advantage in samples of children tested. It would also reveal whether any other professionals had observed any beneficial effects of an earplug in their own cases. Additionally, retesting of "earplug cases" would afford an opportunity to assess the reliability of the test.

The following sections of this report document the steps taken in pursuit of these main goals and the results obtained.

Independent Testing of the Monaural Advantage

A primary purpose of this study was to investigate the validity of the monaural advantage effect claimed by Green. Validity was investigated in three ways. First, a sample of children who had been tested with the ACT prior to this study, found to have a monaural advantage, and prescribed an earplug for the poorer scoring ear were retested by an independent researcher, blind to initial test scores. Second, ACT scores for a normal control sample were compared to that of the follow-up sample. Finally, professionals who have used the ACT were interviewed to determine whether or not a monaural advantage effect had been observed during their use of the test. Statistical analysis of ACT scores and data from interviews were used for the purpose of answering the following questions:

- Does the selected sample of children exhibit a significant monaural advantage on retesting?
- Are there significant differences in monaural advantage scores between this sample and that of a normal sample of children?
- Have other users of the ACT found monaural advantages?
- Are there observable developmental trends in ACT performance in the selected follow-up sample?

Subjects were 34 students in St. Albert School District No. 3 who had previously been tested using the ACT and for whom a therapeutic earplug had been recommended. Mean age of the group at initial testing was 9.7 years (Standard Deviation (SD) = 2.6) with a range of 6 to 15.5 years; at retest, mean age was 11.8 years (SD = 2.9) with a range of 8 to 18.4 years. Grade placement at the time of retesting was from Grade 2 to Grade 12 and two students were no longer attending school. Consent for testing was obtained by the researcher during telephone interviews with parents or guardians.

During the 1989-1990 school year, the project researcher administered the ACT to students in their respective schools, with the exception of one child who was tested in his home. School principals attempted to provide a quiet room for assessments; however, the normal activities of a school setting were sometimes intrusive. In some cases these distractions may have influenced student performance.

Students were tested without their earplugs following administration procedures recommended in the ACT Manual. Student responses were tape recorded. Where possible, conditions of the retest were identical to those in the administration of the initial test. Tape recorded responses were scored by Green, blind to the conditions of testing. Green's scores and those of the researcher for 32 cases were tabulated by the researcher and statistically analyzed.

Monaural Advantage Effect on Retest

Mean ACT scores and standard deviations for initial testing and retesting by the researcher are summarized in Table 1.

Table 1: Comparison of ACT Mean Scores: Initial and Retest
N = 34

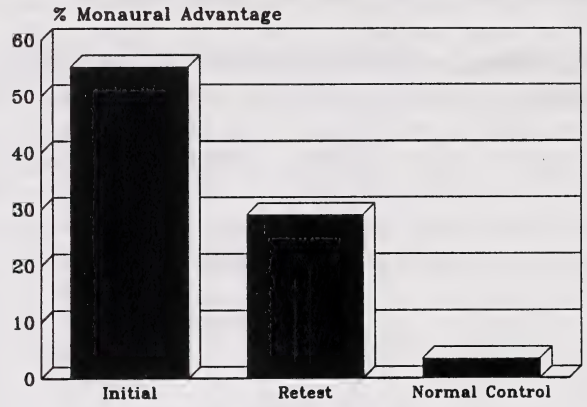
Variable	Initial Score		Retest Score	
	Score	(SD)	Score	(SD)
Left	74.4	(20.0)	80.3	(19.2)
Right	73.1	(16.9)	82.6	(12.9)
Binaural	55.0	(13.0)	69.7	(15.3)
Mean	67.5	(13.5)	77.6	(13.8)
Abs. Ear Diff.*	18.6	(12.5)	13.9	(9.6)
Mon. Adv.*	28.1	(9.4)	18.7	(10.1)
% Ear Diff.*	13.2	(9.4)	8.6	(6.0)
% Mon. Adv.*	55.2	(29.3)	29.0	(19.3)

* Calculations are based on the full data rather than the left, right, and binaural mean scores in the table.

The mean Left, Right, and Binaural scores increased over the two year interval between tests (L = +5.9; R = +9.5; B = +14.7), as might be expected. In his work with children, Green has found that scores normally increase approximately seven points per year until approximately age 12 years, after which performance of children is comparable to that of adults (Green & Josey, 1989). This increase appears to be a function of developmental changes in attention, memory, and vocabulary knowledge. On retest, the single ear scores for this sample increased less than might normally be expected. The binaural score remained lower than the highest single ear score on both administrations of the test, with a difference of -28.1 points on the initial test and -18.7 points on the retest. Calculated as a percentage

score, the mean monaural advantage for this sample was 55.2% on the initial test and 29% on retest. Green's research suggests that a monaural advantage of 3.5% is found in normal children (Green & Josey, 1989). Although the monaural advantage found on retest is less than on initial testing, it remains significantly large in comparison to that of a normal control sample ($t = 12.97$; $df = 164$; $p = 0.000$). This comparison is illustrated in Figure 1.

Figure 1: Percentage Monaural Advantage: Initial and Retest



Summary

A monaural advantage, as measured by performance on the ACT, was present on retesting by an independent researcher approximately two years after initial testing by Green. This result supports the concept of a monaural advantage effect, as claimed by Green. The effect was found to be reproducible and stable, although of reduced magnitude over this time period.

Comparison of ACT Scores for Follow-Up and Normal Samples

A second procedure used to investigate the monaural advantage effect was to statistically compare the performance on retesting of the follow-up group with that of a sample of children who did not display a monaural advantage on testing with the ACT. Subjects in the normal sample were students registered in two schools in Edmonton, Alberta. The data for this group are summarized in a paper by Green and Josey (1989), submitted for publication.

Subjects

The normal group was composed of 132 children with a mean age at the time of testing of 11.0 years (SD = 2.3), average academic achievement, and at least average intelligence as measured by individual and group intelligence

tests (approximate verbal IQ 99.1; nonverbal IQ 101.6). The sample of 66 boys and 66 girls was selected by classroom teachers.

Results

A summary of the mean ACT scores and standard deviations for the normal sample and the retest mean scores of the follow-up sample are presented in Table 2.

Table 2: Comparison of ACT Scores: Follow-Up and Normal Groups

Variable	Follow-Up Group (N = 34) Score	(SD)	Normal Group (N = 132) Score	(SD)
Left	80.3	(19.2)	87.0	(22.5)
Right	82.6	(12.9)	88.1	(22.2)
Binaural	69.7	(15.3)	90.1	(22.2)
Mean	77.6	(13.8)	88.4	(21.3)
Abs. Ear Diff.*	13.9	(9.6)	9.2	(7.7)
Mon. Adv.*	18.7	(10.1)	1.9	(10.7)
% Ear Diff.*	8.6	(6.0)	5.8	(5.4)
% Mon. Adv.*	29.0	(19.3)	3.5	(13.7)

* Calculations are based on the full data rather than the left, right, and binaural mean scores in the table.

Although the two groups are relatively equivalent in age and intellectual ability, several differences are evident when comparing ACT scores. The scores for the normal group are similar across all conditions and fall above an arbitrarily selected cutoff score of 80, which is used to separate normal from abnormal performances in adults (L = 87.0 (SD = 22.5); R = 88.1 (SD = 22.2); B = 90.1 (SD = 22.2)). The scores for the follow-up group, while above the cutoff score of 80, are slightly lower than those of the normals for Left and Right conditions. The significant difference between the normal and follow-up groups, however, is in relation to the Binaural score (B = 69.7 vs. B = 90.1). The Binaural score for the follow-up group is 12.9 points lower than the highest monaural score for that group and is 20.4 points below that of the normal group. Considered as a percentage, the follow-up group achieved a monaural advantage of 29%; the normal group 3.5%.

Green has predicted that in normal subjects, Left, Right, and Binaural scores would be very similar, and therefore would be highly correlated (Green, 1984). In comparing the correlations of scores between the normal and follow-up groups, a high correlation between Left, Right, and Binaural scores is evident in the normal group; a significantly lower correlation was found in the follow-up group ($p = 0.000$). These results are summarized in Tables 3a and 3b.

Table 3a: Correlations For Left, Right, and Binaural Scores: Follow-Up Group

	Left	Right	Binaural
Left	1.000	0.2554	0.6155
Right	0.2554	1.000	0.6781
Binaural	0.6155	0.6781	1.000

Table 3b: Correlations For Left, Right, and Binaural Scores: Normal Group

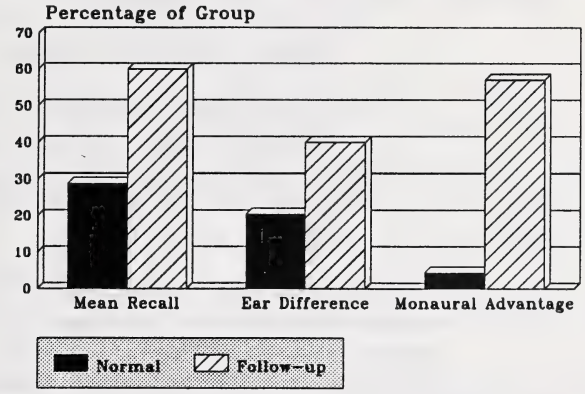
	Left	Right	Binaural
Left	1.000	0.8598	0.8769
Right	0.8598	1.000	0.8526
Binaural	0.8769	0.8526	1.000

Statistically significant differences were found between the normal and follow-up groups for all score calculations:

Mean: $t = -5.43$; $df = 164$; $p = 0.000$*
Ear Difference: $t = 5.56$; $df = 164$; $p = 0.000$*
Percentage Ear Difference: $t = 6.05$; $df = 164$; $p = 0.000$*
Monaural Advantage: $t = 12.97$; $df = 164$; $p = 0.000$*
Percentage Monaural Advantage: $t = 14.98$; $df = 164$; $p = 0.000$*
* two-tailed test

The differences in performance between the two groups are also illustrated in the following graph comparing the percentage of each group achieving abnormal scores.

*Figure 2: Percentage of Groups Achieving Abnormal Scores**



* Note: Mean cut-off is arbitrary.

Summary

The purpose of comparing performance on the ACT of a normal sample with that of the follow-up group, for whom earplugs were recommended, was to determine whether or not statistically significant differences between the groups were present. Analysis of this data indicates that differences between the groups do exist in respect to the norms established for the ACT, with the most significant difference between groups being in the monaural advantage score. Fifty-seven per cent of the follow-up group achieved an abnormal monaural advantage score, in comparison to 4.5% of the normal sample.

Reports of Monaural Advantage from Interviews

Distribution of the ACT has been limited to a small number of speech and language pathologists, psychologists, and medical personnel who have used the instrument in their practices for assessment and research purposes. The following individuals, representative of these disciplines, were interviewed by telephone:

Dr. Chad Howells, Psychologist, Alberta Mental Health Services, Stettler, Alberta

Mr. Tom Zeiffle, Psychologist and Principal, Bonanza School, Spirit River School Division, Spirit River, Alberta

Dr. Manford Barber, Audiologist and Speech Pathologist, Hearing Clinic, Psychiatric Unit, Menninger Clinic, Topeka, Kansas

Dr. Don Hepburn, Consulting and Clinical Psychologist, Ponoka, Alberta

Dr. Scott Sellick, Clinical Psychologist and Adjunct Professor, Lakehead University, Thunder Bay, Ontario

Dr. C. Wilkes, Psychiatrist and Pediatrician, Alberta Mental Health Services, Lethbridge, Alberta

Ms. Janet Bates, Speech and Language Pathologist, County of Strathcona, Sherwood Park, Alberta

Dr. Roger Gervais, Consulting and Clinical Psychologist, Edmonton, Alberta.

The interviewees have used the ACT with varying degrees of frequency over a period of from one to five years. All reported finding selected cases in which clients achieved higher single ear rather than both ear scores, resulting in the prescription of an earplug. There were several reports of cases in which the monaural effect was unstable, that is, not present on retesting. The reason for this finding is unclear. No formal follow-up of children who were found to have a monaural advantage and prescribed earplugs had been attempted at the time of interview.

Developmental Patterns in ACT Performance

Comparison of ACT test and retest scores was undertaken to investigate the monaural advantage effect. This data did, however, afford an opportunity to investigate developmental trends in scores for the follow-up sample under consideration. An additional analysis of ACT test and retest scores was done by comparing the subjects on the basis of whether or not the higher scoring ear on initial testing was the right or the left ear. The results are summarized in Tables 4 and 5.

Table 4: Comparison of Initial and Retest ACT Mean Scores and Standard Deviations: Group = Right Ear > Left Ear
N = 16

Variable	Initial Test Score	(SD)	Retest Score	(SD)
Left	61.2	(17.9)	74.7	(13.5)
Right	80.8	(18.3)	82.0	(11.5)
Binaural	54.7	(14.2)	66.4	(9.8)

Table 5: Comparison of Initial and Retest Mean ACT Scores and Standard Deviations: Group = Left Ear > Right Ear
N = 16

Variable	Initial Test Score	(SD)	Retest Score	(SD)
Left	84.9	(14.8)	85.0	(22.1)
Right	67.1	(13.2)	83.2	(14.4)
Binaural	55.2	(12.3)	72.5	(18.5)

Several observations can be made regarding the changes in scores over the two year period between initial and retest administrations of the ACT. Green has suggested that children's scores normally increase approximately seven points per year until age 12, at which time their performance is comparable to that of adults (Green & Josey, 1989). In both groups, normal increases occurred in the poor ear and binaural scores. In contrast, the higher scoring ear on initial test showed very little change on retest. This finding seems unusual; while it may be an artifact, there is also the possibility that it reflects some abnormality in development. The reasons for these findings cannot be explained at this time.

Summary of Findings in Respect to Monaural Advantage Effect

A primary purpose of this study was to determine whether or not the monaural advantage claimed by Green is a valid effect, that is, reproducible and stable over time. The monaural advantage effect was investigated in three ways: through retesting of a selected sample of children who had shown a monaural advantage on initial testing; through comparison of the scores of the selected sample with those of a normal sample; and through interviews with individuals who have used the ACT.

Green's research suggests that a monaural advantage of 3.5% may be considered normal in children (Green & Josey, 1989). On initial testing, the selected sample achieved a monaural advantage of 55%; on retest the monaural advantage was 29%. Although the monaural advantage found on retest was less than on initial testing, it remains significantly large according to Green's suggested guidelines.

A second method for assessing the validity of the monaural advantage was to determine whether or not a monaural advantage was present in a normal sample. Performance on the ACT of the selected sample and a normal sample was compared statistically to determine whether or not differences

between the groups were present. Statistically significant differences between the groups were found in respect to the norms established for the ACT, with the most significant difference between groups being in the monaural advantage score (follow-up group = 29%; normal group = 3.5%). Approximately 57% of the follow-up group achieved an abnormal monaural advantage in comparison to 4.5% of the normal group.

The monaural advantage effect was also investigated through interviews with professionals who are experienced in the use of the test. Reports indicate that a monaural advantage effect has been observed by all interviewees; however, in some cases, this effect was not evident on retesting. This instability in retest results has not been explained at this time.

The data collected for the follow-up sample enabled some investigation of developmental trends in respect to performance on the ACT. An abnormal pattern of development is indicated with a monaural advantage persisting over the interval between tests. Little improvement was observed in the higher scoring ear, although a normal increase was observed in the lower scoring ear and in the binaural score.

Conclusion

These results may be considered to support the validity of a monaural advantage effect. The effect was found to be reproducible by the project researcher and others using the ACT. The incidence of a monaural advantage was more than 12 times greater in the selected sample than in a normal sample of comparable age and intellectual ability. In the follow-up sample, the monaural advantage, although reduced in magnitude, was stable over a two year period. In some children, the monaural advantage does not appear to be stable, a phenomenon which cannot be explained at this time. Another unexplained finding is the apparent lack of improvement in the higher scoring ear, although near-normal increases were observed in the lower scoring ear and binaural conditions.

Evaluation of the Effects of Earplug Wearing

Interview Data

A follow-up was implemented of those students from St. Albert School District No. 3 for whom an earplug was prescribed. In most general terms, the question to be answered was "Does an earplug work, that is, provide a therapeutic effect?" Questions of interest were:

- Did parents implement the recommendation to have an earplug fitted, and if so, to what extent was it worn?
- Are there positive and/or negative effects associated with earplug wearing?
- What factors contribute to successful or unsuccessful adjustment to wearing an earplug?

Procedure

The effects of wearing an earplug were investigated through analysis of responses to interviews conducted with parents of students for whom an earplug was prescribed, with the students themselves, and with teachers who were able to observe the behavior of the students with and without the earplug. Other data were provided by anecdotal comments in student records, report card comments, and reports from a survey conducted by St. Albert School District No. 3 personnel (St. Albert School Dist. No. 3, 1987).

Personal interviews with teachers were conducted when feasible; additional information from teachers was obtained through telephone interviews and anecdotal records documenting student behavior. Teacher reports were unavailable for 17 students, for several reasons. In some cases, teachers were unable to recall or did not have documentation of specific behavior of children taught in previous years. Several students changed schools or received their earplugs during the summer; consequently, no teacher was able to observe "pre-plug" and "post-plug" behavior. One teacher has relocated and was unavailable for interview. In general, special education teachers were able to provide the most comprehensive reports, probably because lower enrolments enable them to become more familiar with their students.

Parents were interviewed by telephone, using a semi-structured questionnaire (see Appendix B) requesting responses to a variety of questions as well as providing opportunities for unsolicited comments; students were interviewed at the time of their ACT retest (see Appendix A). Following completion of the interviews, the results were analyzed and cross-referenced to determine similarities and differences in perceptions of parents, students, and teachers. Wearing time was verified through comparison of the parents' reports with those of the children and teachers. Common themes have been clustered in tabular form (see Table 7, p. 23).

Interview responses have been grouped according to the following categories:

- *"Wearers" (N=17)* were those students who are currently wearing the earplug, and have done so at least during school hours for six months or longer. Typically, these students remove the earplug only for strenuous activities such as participation in sports. Of this group, 59% wear the earplug daily during their waking hours; 41% wear the earplug only during school hours. Mean wearing time for this group is approximately nine hours daily over a period of from six months to five years.
- *"Non-Wearers" (N=11)* were those who have not worn the earplug at least during school hours and for a minimum of six months. In general, children in this group have worn the earplug sporadically or not at all. Mean wearing time for this group was approximately four hours daily over a period of four weeks (range zero to 16 weeks).
- *"Discontinued Wearers" (N=10)* were those who wore the earplug at least during school hours for a period of six months or longer and have subsequently discontinued wearing. Of this group, most reported that they discontinued wearing because it did not seem to be helping; however, three students reported that the earplug helped but that they discontinued wearing because of embarrassment. Mean wearing time for this group was approximately 6.5 hours daily over a period of one year (range six months to four years).

Results

Positive Effects

Parent perceptions of positive therapeutic effects associated with earplug wearing are summarized for all groups of children in Table 6. In total, 44.7% of the parents reported that they believed the earplug helped their child; 18.4% were unsure that the earplug helped; 36.9% reported that the earplug did not help. One parent described an increase in the child's frustration while wearing an earplug. This child discontinued wearing after approximately two months.

Table 6: Parent Perception of Positive Earplug Effect

Group	Helped	Unsure	Didn't Help	Total
Wearers	14 (82%)	3 (18%)	0	17
Non-Wearers	0	2 (18%)	9 (82%)	11
Disc. Wearers	3 (30%)	2 (20%)	5 (50%)	10

In general, parents, children, and teachers reported similar positive effects of wearing an earplug. These responses are summarized in Table 7.

Table 7: Reported Positive Effects of Earplug Wearing

Effects	Responses *		
	Parent	Child	Teacher
Improved understanding of speech	15 (33%)	6 (25%)	5 (21%)
Improved attention	5 (11%)	2 (8%)	4 (17%)
Less bothered by noise	4 (9%)	2 (8%)	1 (4%)
Improved academic achievement	8 (18%)	5 (21%)	6 (25%)
Calmer, less frustrated	7 (15%)	0	3 (12%)
Improved self-concept	3 (7%)	2 (8%)	5 (21%)
Positive attitude to school	3 (7%)	7 (30%)	0

* In most cases, multiple effects reported.

The following represent a selection of comments typical of those provided by parents and teachers who reported positive therapeutic effects:

"The child asks questions now, didn't used to."

"The child seems to understand better when spoken to."

"My child reports that it's easier to listen."

"Instructions do not have to be repeated so frequently in the classroom."

Several students offered comments as well: *"I used to think I was stupid before I had the plug"; "My friends know when I'm not wearing my earplug, because I frequently ask to have information repeated."*

Undesirable Effects

Parents were asked to report if there were any "bad" effects from their child wearing an earplug. The term "bad" was not defined. Responses are summarized in Table 8.

Table 8: Parent Perception of Undesirable Earplug Effects

Group	Yes	Unsure	No	Total
Wearers	2 (12%)	1 (6%)	14 (82%)	17
Non-Wearers	6 (55%)	1 (9%)	4 (36%)	11
Disc. Wearers	2 (20%)	0	8 (80%)	10

Of the total group, 26.3% of parents reported a "bad" or undesirable effect for the child wearing an earplug; 5.3% were unsure; and 68.4% reported no observation of bad effects. Two common undesirable effects emerged: complaints of physical discomfort such as itchiness or soreness, and emotional effects caused by embarrassment. While three children experienced ear infections, the parents reported that wearing an earplug was not causally related to these infections.

Children's reports regarding undesirable effects from wearing an earplug were similar to those of the parents. Sixty-eight per cent of parents and 42% of children reporting undesirable effects indicated concern about emotional effects such as self-consciousness and embarrassment. Thirty-two per cent of parents' and 58% of childrens' reports identified physical discomfort as a concern. One child reported that cleaning the earplug was difficult, and two reported that they believed the earplug distorted their hearing.

Parents of children who have discontinued wearing an earplug tended to qualify their reports about earplug effects because of the length of time since wearing had occurred, and because other factors such as change of schools or program, or maturity, were recognized as contributing to behavioral change. Nevertheless, several parents of children who have discontinued wearing, reported positive changes associated with earplug wearing: *"It seemed to help with self-confidence"; "I didn't have to repeat myself so many times"; "Some improvement was observed in absorbing information, school marks improved and the child appeared to be less frustrated."*

Educational Services Provided to Follow-Up Group

School records and parent reports indicate that the students in this study have tended to exhibit academic delays since school entry, particularly in language arts and mathematics. Several mothers reported that they were aware of the child's "differentness" prior to school entry. It is clear that a variety of strategies have been attempted by schools and parents to provide academic assistance to these students. There do not appear to be differences between wearers and non-wearers in the types of services accessed. The program adaptations reported by parents or documented in school records are summarized in Table 9.

Table 9: Numbers of Students Provided Educational Assistance

Program Adaptation	Wearers	Non-Wearers	Disc. Wearers
Repeated Grade	2	2	2
Resource Room	7	3	2
Alternate Program*	6	3	5
Tutor	2	1	3
Teacher Assistant**	2	0	0

* Includes transition, low enrolment class, learning assistance center, readiness class, private school, or transfer from French Immersion to English program.

** Part-time

Other Findings

Pharmacological treatment of learning problems in children with attentional deficits is sometimes recommended. Of the total follow-up group, 18.4% have been treated in the past, with parents recalling no improvement in behavior as a result of medication. Undesirable side effects included stomach upset, tearfulness, and/or extreme lethargy.

A variety of factors contribute to improved academic achievement and behavior. While positive effects related to earplug wearing were reported for 44.7% of students, parents of wearers and non-wearers identified other factors which they considered to have significantly contributed to their child's improved performance: changes in program, increased maturity, repeating a grade, resource room assistance, other school services (counselling, speech, and language therapy), good teachers, and family support.

For the most part, these children were not perceived as disciplinary problems by their parents, but rather as being unhappy, confused, and unsuccessful at school.

Summary of Reported Effects of Earplug Wearing

Data from parents and school records indicate that in 43/46 (93.5%) of cases, parents did comply with the recommendation to have an earplug fitted. Among the 38 students available for follow-up in this study, the full-time wearers (44.7%), wear their earplug for an average of nine hours daily. This level of adherence compares favorably with that reported for patients of medical and mental health agencies and practices. In a survey of the literature, Meichenbaum and Turk report that *"although the precise level of treatment non-adherence is difficult to determine, estimates range from a low of 4% to a high of 92%, with the most typical range being from 30% to 60%....the incidence of adherence with medication averages 30% to 35%"* (Meichenbaum & Turk, 1987, p. 21).

Multiple but individualistic positive effects associated with wearing were reported, including better understanding of speech, improved attention, less sensitivity to noise, improved academic achievement, less frustration, improved self-concept, and a more positive attitude to school. Reports by parents, teachers, and students were similar. Positive effects associated with earplug wearing documented in cases submitted by other professionals are also similar to those described by participants in this survey. While these positive effects are based on anecdotal reports, and are impossible to verify objectively, it is noteworthy that they are reported for a relatively large number of students (44.7%).

Negative effects associated with earplug wearing were also reported: physical discomfort and negative emotional consequences because of embarrassment, fear of being teased, and increased attention from the curious. Two students believed that their hearing was distorted while wearing an earplug. No medical problems were associated with earplug wearing. In general, those students who are wearers of the earplug reported fewer concerns than non-wearers in respect to either discomfort or emotional effects, with several wearers reporting that they are no longer conscious of it.

A number of factors appear to facilitate adjustment to wearing an earplug. Parent belief in its effectiveness is clearly associated: 82.4% of parents of earplug wearers believe that earplug wearing is associated with positive therapeutic benefit; 36.4% of non-wearers' parents reported benefit. Child belief that the earplug helps is also a significant factor: 76.5% of wearers and 14.3% of non-wearers reported that they believed that earplug wearing

was beneficial. Fewer concerns about discomfort and embarrassment were reported by earplug wearers: 76.5% of wearers as opposed to 45.5% of non-wearers reported no problems associated with wearing an earplug.

In general, earplug wearers and their parents tend to believe that an earplug helps, and these children seem to have fewer problems of adjustment to wearing. In contrast, among those who are not wearers, fewer parents and children believe it helps and greater problems of adjustment are reported. The reasons for these differences in adjustment between wearers and non-wearers can not be ascertained at this time; however, several possibilities might be considered. A placebo effect may be occurring, causing change because of novelty and strong belief in its efficacy. If so, it seems to be a particularly strong effect, given the level of adherence to wearing and the length of time some children have worn the earplug with relatively little monitoring by parents and teachers to encourage wearing. A second possibility is that the earplug is associated with some physiological change in cerebral function. Reports of the reduction or elimination of hallucinations in psychiatric patients suggests that this may be so (Birchwood, 1986; Howells & Rice, 1990; James, 1983; Done, Frith, & Owens, 1986).

Teacher attitude towards this treatment may also impact upon adjustment to wearing an earplug, by encouraging compliance and facilitating understanding and acceptance by the child's classmates, particularly in the initial stages of wearing.

Special education services have been accessed equally by both earplug wearers and non-wearers. A review of the educational adaptations made available to earplug wearers, non-wearers, and discontinued wearers suggests that no trends are evident which would differentiate among the groups. All have demonstrated significant academic delay, for which a variety of remedial strategies have been applied. No conclusions can be made regarding differences in allocation of special education services to these groups since placement is contingent upon many factors, including need, availability of service, ability of classroom teachers to accommodate program modifications, and parent preference. Medication for attention deficit and/or hyperactivity has been prescribed for 21.1% of this sample. With the exception of one case in which therapeutic benefit is reported, medication was reported by parents to have deleterious side effects and no beneficial effect on academic performance.

Although nearly half of the parents reported positive effects associated with earplug wearing, numerous other factors affecting school performance were cited: special education services, exceptional classroom teachers, counselling, and speech therapy services.

Statistical Comparison of Earplug Wearers and Non-Wearers

Statistical analysis of ACT retest scores of the follow-up group was conducted to determine whether or not significant differences were present which could differentiate between earplug wearers and non-wearers.

Subjects

At the time of initial test, mean age for the wearers group was 9.47 years (SD 2.43) and for the non-wearers 9.95 years (SD 2.85). On retest, mean age of the wearers group was 11.15 (SD 2.64) and for the non-wearers group 12.41 (SD 3.16). Mean interval between tests for the wearers group was 1.68 years, for the non-wearers group 2.46 years. Mean IQ scores were calculated for each group (wearers: verbal IQ (VIQ) 92.81 (SD 11.12), performance IQ (PIQ) 109.36 (SD 11.89), full scale IQ (FSIQ) 100.14 (SD 8.71); non-wearers: VIQ 98.00 (SD 12.58), PIQ 99.6 (SD 12.15), FSIQ 101.54 (SD 5.25)).

Results

Tables 10 and 11 summarize mean initial and retest ACT scores and standard deviations for wearers and non-wearers.

Table 10: Initial and Retest Scores for Wearers (N=17)

Variable	Initial Scores Score (SD)	Retest Scores Score (SD)
Left	79.8 (16.4)	83.9 (20.7)
Right	72.3 (12.9)	83.2 (13.9)
Binaural	55.4 (10.6)	71.5 (17.1)

Table 11: Initial and Retest Scores for Non-Wearers (N = 11)

Variable	Initial Scores Score (SD)	Retest Scores Score (SD)
Left	70.6 (20.8)	78.2 (16.9)
Right	76.9 (22.7)	82.4 (12.6)
Binaural	58.6 (16.8)	68.5 (13.9)

Initial ACT test scores show no significant difference between wearers and non-wearers, with mean scores for both groups being below normal according to an arbitrarily selected score of 80. Binaural scores for both groups were less than either single ear score, resulting in enlarged monaural advantages (wearers: 56.44% (SD 35.53); non-wearers: 46.57% (SD 23.39)).

On retest, no significant difference between wearers and non-wearers was found, the relationship between the scores being similar to that present on the first test: binaural scores remained reduced in comparison to single ear scores and an enlarged monaural advantage was present (wearers: 30.03% (SD 21.41); non-wearers: 28.17% (SD 18.22)).

A difference between wearers and non-wearers in respect to ear difference scores (R-L) was observed when frequencies of subjects achieving abnormal ACT scores were compared. In this sample, ear difference increased in wearers and decreased in non-wearers. This may reflect greater stability in ear differences in the wearers group. These results are illustrated in Figures 3 and 4.

Figure 3: Percentage of Wearers Achieving Abnormal Scores at Initial and Follow-Up on Measures of Ear-Difference and Monaural Advantage

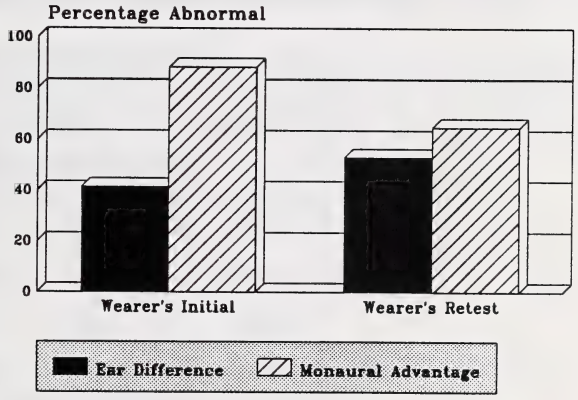
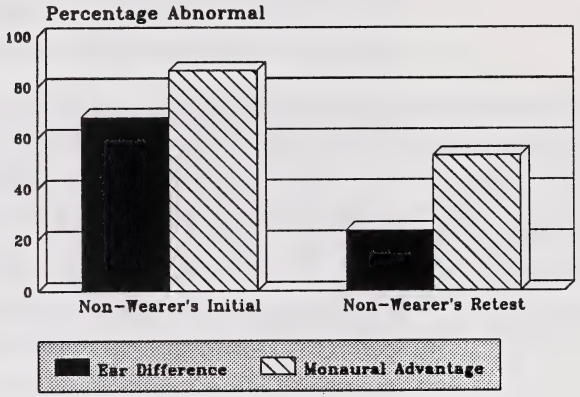


Figure 4: Percentage of Non-Wearers Achieving Abnormal Scores at Initial and Follow-Up on Measures of Ear-Difference and Monaural Advantage



No statistically significant differences between earplug wearers and non-wearers were found when comparisons between groups were made on the basis of initial and retest scores on the ACT, age or gender. A significant difference was found, however, when mean IQ scores were calculated for wearers and non-wearers groups. The comparison between groups on the basis of mean intelligence scores is summarized in Table 12.

Table 12: Mean IQ Scores for Wearers and Non-Wearers

Variable	Wearers		Non-Wearers	
	Score	(SD)	Score	(SD)
VIQ	92.8	(11.1)	98.0	(12.6)
PIQ	109.4	(11.9)	99.6	(12.2)
FSIQ	100.1	(8.7)	101.5	(5.3)
VIQ-PIQ	-15.6	(14.6)	-1.8	(17.1)

The relationship between mean VIQ and PIQ scores is quite different for each group, the mean difference between VIQ and PIQ being 15.6 points (SD 14.6) for wearers and 1.8 points (SD 17.1) for non-wearers. This finding suggests that the wearers group may have a more specific language deficit or disability perhaps related to impaired left hemisphere functioning. The equivalence of VIQ and PIQ scores for the non-wearers group, in contrast, suggests that a more generalized disability may be impairing academic achievement, perhaps related, for example, to emotional or attentional problems.

Summary

A statistically significant difference between wearers and non-wearers was found when the difference between VIQ and PIQ scores for each was compared. The mean difference between verbal and performance IQ was 15.6 points for wearers and 1.8 points for non-wearers. This was an unexpected finding, the explanation of which will require further investigation.

No statistically significant differences were found which might differentiate between earplug wearers and non-wearers when the groups were compared on performance on the ACT, by age, or by gender.

Conclusions in Respect to Earplug Wearing

Anecdotal reports from parents, students, and teachers indicate that for approximately 45% of this sample, earplug wearing is associated with positive effects on speech comprehension, behavior, and academic achievement. Reported negative effects were, in general, related to discomfort and embarrassment. Objective measures supporting these reports are limited and the contribution of other factors such as program modifications or treatment effects cannot be evaluated at this time. Despite these limitations, the number and consistency of reported beneficial effects suggests that further investigation of the earplug as treatment is warranted.

A statistically significant difference between wearers and non-wearers was found when the difference between VIQ and PIQ scores for each was compared. This was an unexpected finding, the explanation of which will require further investigation.

Assessment of the Usability, Validity, and Reliability of the ACT

Assessment of the "usability" of the ACT was established as an objective of this research project. In consideration of the data available for analysis, validity, inter-rater reliability, test-retest reliability, and "usability" in respect to facility of test administration and the applicability of test results to planning treatment interventions were examined. Validity and reliability data were based on statistical analysis of ACT scores collected for the purpose of this investigation. Other aspects of "usability" were determined through telephone interviews with eight professionals who are experienced in administration of the ACT.

Validity of the ACT

Evidence of the validity of an instrument and of the construct it measures accumulates gradually. The ACT is a relatively new instrument which measures an effect which has not been widely investigated. It is to be expected, therefore, that information about its validity will be limited at present. On the basis of current knowledge, however, observations can be made about several aspects of its validity.

The ACT purports to assess speech comprehension problems in children and adults. Face validity appears to be satisfactory; that is, the test requires recall of items using language similar to that used in real-life situations. There is no equivalent test with which the ACT can be compared; however, anecdotal evidence suggests that children who score abnormally on the ACT have been identified by their parents or teachers as having speech comprehension problems. An indicator commonly reported by parents and teachers during interviews with this writer was that these students appeared to have a hearing loss, but none was found upon audiological testing.

At the time of its development, Green found that adult normal groups and psychiatric patient subgroups tended to score differently on the ACT (Green, 1984). Available data enables some assessment of the validity of the ACT through comparison of the performances of normal adults, normal children, and learning disabled children. A comparison of these groups was enabled through development of a data base composed of ACT scores provided by a number of individuals:

Mr. Tom Zeiffle, Psychologist and Principal, Spirit River School Division, Spirit River, Alberta

Dr. Scott Sellick, Clinical Psychologist and Adjunct Professor, Lakehead University, Thunder Bay, Ontario

Dr. Paul Green, Psychologist, Edmonton, Alberta

Dr. Roger Gervais, Consulting and Clinical Psychologist, Edmonton, Alberta

Dr. Ruben Lang, Psychologist, Alberta Hospital, Edmonton, Alberta

Ms. Janet Bates, Speech and Language Pathologist, County of Strathcona, Sherwood Park, Alberta.

A summary of this data is presented in Table 13.

Table 13: Sample Size of Groups of Heterogeneous Children, LD Children, Normal Children, and Normal Adults Tested With the ACT

Group No.	N
1. Children (Heterogeneous)	17
2. LD Children	44
3. Normal Children	38
4. LD Children	179
5. Children (Heterogeneous)	99
6. Normal Children	132
7. Normal Adults	45
8. Normal Adults	61
9. LD Children	125
10. LD Children	88
11. LD Children	73
Total Sample Size	901

A summary of ACT mean scores for this sample is presented in Table 14.

Table 14: Summary of Findings on the ACT from 901 Cases in 11 Groups

Group	N	Mean (L+R+B) /3 Cutoff ≤ 80	Percent Ear Difference Cutoff ≥ 10%	Percent Mon Adv. Cutoff ≥ 20%
Normal Children				
3	38	96.75	4.59	4.82
6	132	88.41	5.80	3.46
Normal Adults				
7	45	99.43	3.07	4.14
8	61	99.93	3.85	3.23
LD Children				
2	44	70.75	8.23	11.79
4	179	73.83	10.51	35.47
9	125	73.59	7.26	16.52
10	88	65.50	5.98	18.47
11	73	71.61	5.98	26.05
Children (Heterogeneous)				
1	17	60.16	13.72	36.45
5	99	67.36	8.05	13.62

Two factors limit the conclusions which can be drawn from analysis of these data. First, selection criteria vary from group to group, and are ambiguous for the heterogeneous groups. Second, while the LD groups were chosen on the basis of average intellectual ability and significant academic underachievement, no information was available enabling identification of the specific disability or disabilities of these students.

The normal children and adults, in all cases, achieved mean scores within the statistically normal range. In contrast, in the LD and heterogeneous groups, a number of abnormal scores are present. All children in the LD and heterogeneous groups scored below the arbitrarily suggested cutoff (80) for mean left, right, and binaural scores and 42.9% (3/7 groups) showed an abnormal monaural advantage of greater than 20%. In all cases, LD children demonstrated larger percentage ear difference scores than did the normal adults and normal children.

To summarize, data from this sample of 901 cases suggests the following conclusions:

- Normal adults and children achieved mean, ear difference, and monaural advantage scores that are similar, and within the statistically normal range.

- All groups of LD children achieved abnormally low mean scores. In addition, the monaural advantage scores of the LD groups are two to seven times greater than those of the normal children.
- The heterogeneous groups achieved abnormally low mean scores. While one group showed the most abnormally enlarged monaural advantage of all groups (36%), there is insufficient information to determine the cause for this result. In general, it appears that within the heterogeneous groups, some portion of the sample is demonstrating a monaural advantage.

Reliability of the ACT

Inter-rater reliability was assessed by comparing the scoring of the researcher and Green on ACT protocols for 33 cases retested as part of this study.

Results

Scores obtained by both raters for left, right, and binaural conditions, and the degree of ear advantage calculated from these scores are summarized in Table 15 to illustrate inter-rater reliability.

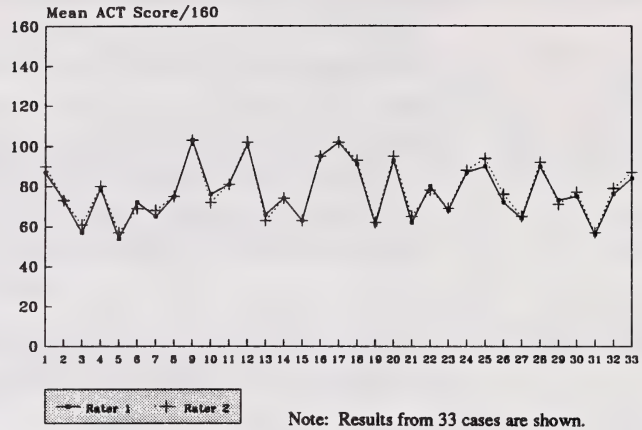
Table 15: Comparison of Mean Scores Obtained by Two Raters
N = 33

Variable	Rater 1 Score	(SD)	Rater 2 Score	(SD)
Left	80.3	(19.2)	82.1	(19.6)
Right	82.6	(12.9)	84.1	(13.1)
Binaural	69.7	(15.3)	70.4	(15.9)
Mean	77.6	(13.8)	78.9	(13.8)
Abs. Ear Diff.*	13.9	(9.6)	15.2	(10.4)
Mon. Adv.*	18.7	(10.1)	20.2	(9.9)
% Ear Diff.*	8.6	(6.0)	9.3	(6.4)
% Mon. Adv.*	29.0	(19.1)	31.4	(19.7)

* Calculations are based on the full data rather than the left, right, and binaural scores in the table.

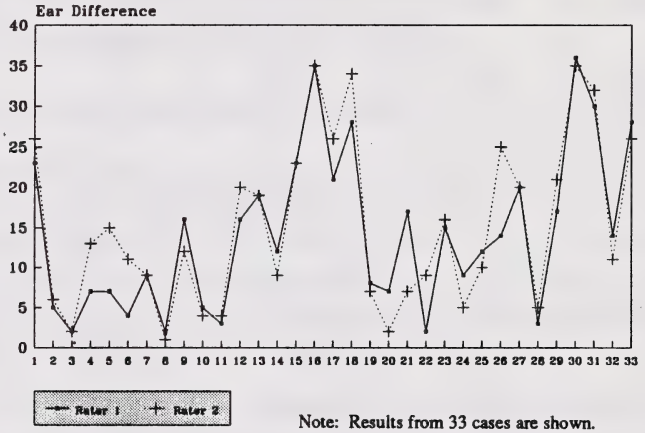
Inter-rater reliability was assessed through correlation of scores from rater 1 and rater 2. These are reported in Table 16 (page 37). All correlations are positive and significantly high, as illustrated in Figures 5, 6, and 7.

Figure 5: Mean ACT Scores Obtained by Independent Raters



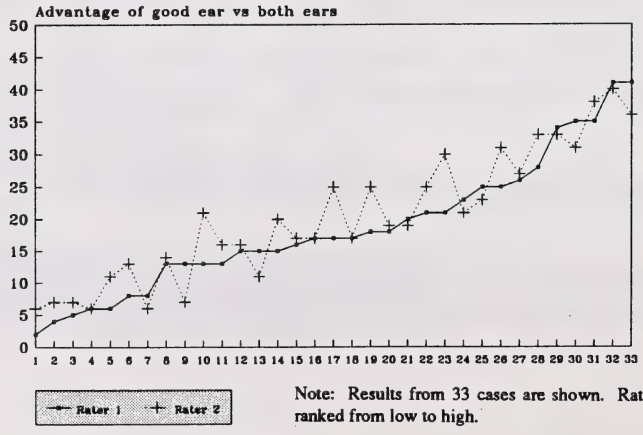
Note: Results from 33 cases are shown.

Figure 6: Ear-Difference Scores Obtained by Independent Raters



Note: Results from 33 cases are shown.

Figure 7: Monaural Advantage Scores Obtained by Independent Raters



Note: Results from 33 cases are shown. Rater 2 scores ranked from low to high.

Table 16: Correlations Between Raters 1 and 2 for Test Variables

Variable	Correlation
Left Ear Score	0.985*
Right Ear Score	0.969*
Binaural Score	0.977*
Mean Score	0.987*
Absolute Ear Difference Score	0.911*
Percentage Monaural Advantage Score	0.942*

* P = 0.001

Test-retest reliability was assessed through a comparison of initial test scores and retest scores obtained by the first rater for the sample of students. These results, summarized in Table 1 (p. 13), were discussed in a previous section of this report (**Independent Testing of the Monaural Advantage**), describing the investigation of the replicability of the monaural advantage.

Reliability was established for single ear and mean scores; however, prediction, as measured through correlation and statistical tests of significance, is less strong for binaural scores, direction and magnitude of ear difference, and magnitude of monaural advantage. Positive correlations between initial test and retest were: Left = 0.6055, p = -0.001; Right = 0.5172, p = -0.001; Binaural = 0.3688; Mean = 0.5958, p = -0.001; Ear Difference = 0.1152; Percentage Ear Difference = 0.072; and Percentage Monaural Advantage = 0.3483.

Because this sample does not represent a normal distribution, assessment of test-retest reliability is limited. Further investigation, using a larger sample and a more normal distribution, is necessary to confirm these results.

Interviews with ACT Users

Usability was also assessed through interviews with professionals who have used the test. Distribution of the ACT has been limited to a small number of speech and language pathologists, psychologists, and medical personnel who have used the instrument in their practices for assessment and research purposes. The following individuals, representative of these disciplines, were interviewed by telephone:

Dr. Chad Howells, Psychologist, Alberta Mental Health Services, Stettler, Alberta

Mr. Tom Zeiffle, Psychologist and Principal, Bonanza School, Spirit River School Division, Spirit River, Alberta

Dr. Manford Barber, Audiologist and Speech Pathologist, Hearing Clinic, Psychiatric Unit, Menninger Clinic, Topeka, Kansas

Dr. Don Hepburn, Consulting and Clinical Psychologist, Ponoka, Alberta

Dr. Scott Sellick, Clinical Psychologist and Adjunct Professor, Lakehead University, Thunder Bay, Ontario

Dr. C. Wilkes, Psychiatrist and Pediatrician, Alberta Mental Health Services, Lethbridge, Alberta

Ms. Janet Bates, Speech and Language Pathologist, County of Strathcona, Sherwood Park, Alberta

Dr. Roger Gervais, Consulting and Clinical Psychologist, Edmonton, Alberta.

A semi-structured interview was conducted which addressed issues related to frequency of use of the test, purposes for its administration, and problems with administration (Appendix C). Additionally, respondents were requested to provide comments regarding the test, use of an earplug as a treatment, and examples of relevant cases.

Results

While some respondents were unable to precisely identify the number of clients with whom the ACT had been used, responses indicate that at least 400 children of school age have been tested using this instrument. The test is also used for assessment of adults in several psychiatric and/or rehabilitation programs.

General findings were as follows:

- Respondents reported finding a monaural advantage in an unspecified proportion of the test group.
- The test is being used to assess differences between binaural and monaural performance, and as a monaurally administered auditory comprehension test.
- It is estimated that earplugs were recommended for approximately 35 - 40 children. No systematic follow-up of these children has been attempted to assess wearing compliance or effects of the treatment.
- One respondent is developing a French version of the ACT for use in Francophone and French Immersion school programs.

Reportedly, the ACT is administered for a variety of purposes: screening, assessment of children and adults, and, to a lesser degree, for research. Four individuals reported that the ACT is used as a standard part of a screening assessment for children and adults. Three use the ACT when assessing children referred because of poor auditory comprehension, inappropriate verbal responses, distractibility, or behavior disorders. Assessment of adults using the ACT appears to occur primarily in psychiatric and/or rehabilitation settings at this time. Two individuals reported use of the ACT for research purposes.

Five respondents reported no difficulty in administering or interpreting the test, with the provision that it was used regularly. Three respondents reported problems with administration of the test and with its format/ construction, leading them to question its appropriateness for young children. Specifically, it was suggested that scores for young children may be depressed because some stories and/or vocabulary are too difficult and the test is long and tiring, inhibiting the sustained attention necessary to perform satisfactorily. Problems with interpretation of test results and communicating the rationale for recommending an earplug to other professionals were reported. It was noted that administrators of the test must be extremely vigilant while recording responses, resulting in fatigue if several tests are administered on the same day.

In general, all individuals reported that they believed that the ACT is a useful test. The following comments were recorded:

> *"It is helpful to have parents watch so they can understand their child's difficulty."*
>
> *"It should be included as part of a standard assessment battery for assessing learning disabled children."*
>
> *"It is clinically useful with adults in deciding whether they would benefit from treatment in a group setting."*
>
> *"There is nothing comparable as a test of auditory memory."*

Anecdotal reports about children whose behavior improved while wearing an earplug were described by several respondents; however, there appears to have been no systematic follow-up to verify the type and magnitude of change, and no specific verification of change attributable to the wearing of an earplug. In general, behavioral changes reported related to increased alertness and improved academic performance at school.

One respondent reported that while several children had been fitted with earplugs upon his recommendation, it was not clearly evident that the treatment was effective and there was some difficulty with obtaining wearing compliance. Non-therapeutic benefits were cited, however, which may impact positively upon the child's performance, most notably a change in the attitude of the parents and school officials towards the child after identification of an auditory problem using the ACT.

Conclusions Regarding ACT Usability

Usability of the ACT was assessed through analysis of test validity, inter-rater reliability, test-retest reliability, and interviews with users of the test.

Conclusions regarding test validity are limited because the ACT is a relatively new test, assessing an effect which has had limited investigation. The ACT does, however, appear to elicit abnormal patterns of results in children who are described as having problems understanding and remembering speech. The ACT also appears to differentiate between normal groups and those identified as having learning problems.

Data from this study support high inter-rater reliability which was consistent for all conditions. This was facilitated by training and using a tape recorder permitting review of scoring if necessary. The ACT may be considered to satisfy requirements for inter-rater reliability.

Test-retest reliability over approximately a twenty-four month period is less dependable than inter-rater reliability. This may be partially attributed to the abnormal nature of the sample. All subjects displayed abnormal patterns of performance so that no normal distribution was present. Satisfactory reliability was established for single ear and mean scores; however, prediction, as measured through correlation and statistical tests of significance is less strong for binaural scores, direction and magnitude of ear difference, and magnitude of monaural advantage.

Interviewees who have used the ACT were in agreement that it is a useful test, particularly for children who appear to have auditory-linguistic and attentional deficits. In general, the test was seen as easy to administer, subject to training and practice. A primary benefit of the test, noted by several, was that observing administration of the test helps parents and teachers to understand the difficulty the child is experiencing in daily situations requiring comprehension of speech.

Some interviewees have recommended use of a therapeutic earplug for selected cases. Wearing an earplug appears to have produced some therapeutic effects, according to the anecdotal reports made available for this

study. These reports, however, must be considered as tentative; follow-up has been inconsistent or lacking, adequate measures of baseline performance are unavailable, and other variables, which may have influenced behavior, cannot be accounted for. In general, professionals who have not used the test are reported to be skeptical of ACT test results and the use of an earplug as a treatment. Those recommending using an earplug as a treatment need to be fully conversant with the theory on which it is based and able to present documentation of its effectiveness.

General Conclusions

The primary purpose of this study was to gather and analyze information regarding the effects of wearing an earplug for a selected group of students with an assessed auditory comprehension deficit. A second purpose was to examine the usability of the ACT. The results of this study support the following conclusions:

- A monaural advantage of 30% was found when the follow-up sample was retested using the ACT approximately two years after initial testing. This constitutes a replication of Green's findings by an independent researcher and must be considered to support his main findings that, in some individuals, speech comprehension is better when listening with one ear rather than both (Green, 1984; Green & Josey, 1989).

- In addition to finding a monaural advantage, which appears to be an abnormal listening pattern, analysis of ACT results indicates that listening performance did not develop normally in this sample of children over the two year interval between test and retest. In considering the group as a whole, results indicate that, in addition to abnormally low scores, the "good ear" score did not increase, although the "poor ear" and binaural scores increased. The reasons for these results, and their implications, cannot be explained at this time.

- Based on information available for the 46 students for whom an earplug was prescribed, 43 were fitted with an earplug. In most cases, therefore, parents did comply with the recommendation to have an earplug fitted, although there was considerable variation within this group in terms of the extent to which the earplug was worn.

- Forty-five per cent of students are wearing an earplug for a mean wearing time of nine hours daily, and have done so over a period of up to five years. Interviews with parents indicate that 45% believe that positive behavioral change associated with earplug wearing has occurred in their children, with the exception of one child. Support for the parent reports was provided by a limited number of classroom teachers. It is concluded that, in a substantial proportion of cases, parents and children perceive the earplug as having therapeutic value.

- Based on the data collected for this study, it appears that wearing an earplug can have both beneficial and problematic effects. Anecdotal reports from parents, children, and teachers were similar in describing beneficial effects: improved understanding of speech, improved attention, less affected by noise, improved academic achievement, less frustration,

improved self-concept, and a more positive attitude to school. No medical problems were reported to be associated with earplug wearing. Two major problems associated with wearing were reported, mainly by non-wearers or discontinued wearers: discomfort and emotional effects such as embarrassment. Unfortunately, objective evidence supporting these reports was limited. It is concluded that a positive effect is associated with earplug wearing for some students. The reasons for this effect cannot be determined at this time and merit further investigation.

- In general, students who wear an earplug seemed to have little difficulty adjusting to it and reported few adverse effects. This is in contrast to non-wearers who tended to report problems of adjustment which seriously limited wearing time. Adjustment appears to be facilitated by parental belief in and support of this treatment. Teacher support, particularly during the adjustment period, is a significant factor as well.

- One statistically significant difference between wearers and non-wearers groups was that wearers have lower mean VIQ than mean PIQ scores on the WISC-R; no discrepancy between mean VIQ and PIQ scores was found for non-wearers. This suggests that the wearers may have a language disability related to left hemisphere impairment. The non-wearers group, in contrast, may have a disability related to attentional or emotional factors. Should this be the case, the effects experienced by both groups may be dissimilar or may impact on adjustment to wearing an earplug.

- Usability of the ACT was assessed through an examination of test validity, inter-rater reliability, test-retest reliability, and interviews with users of the test. The ACT may be considered to be a "usable" test which does measure ear differences indicative of cerebral functioning during language processing, with high inter-rater reliability and adequate test-retest reliability. The test was found to discriminate between statistically normal and abnormal performances in child and adult samples. In general, the test was highly recommended by those who have used it, being particularly commended as a way to illustrate to parents and teachers the degree of difficulty experienced by some children when listening to speech.

Recommendations

- Further investigation of the phenomenon of a monaural advantage is required to determine whether or not there is a physiological basis for this effect.

- Children who display a monaural advantage achieve abnormal patterns of scores on the ACT, and may have anomalies in the development of the auditory modality. Longitudinal investigation of developmental auditory patterns and their relationship to social, emotional, and educational development in this group (both earplug wearers and non-wearers) is warranted.

- Further investigation of the effects of wearing an earplug is recommended. Implementation of this recommendation would require a well designed longitudinal study, in which objective academic, intellectual, and behavioral baseline data were collected, with regular follow-up over an extended time period.

- It is recommended that teachers who have children who are earplug wearers in their classrooms be provided information about the monaural advantage effect and the use of an earplug as a therapeutic treatment. Provision of behavioral checklists is suggested to assist teachers to more accurately monitor effects associated with earplug wearing.

Glossary

Abnormal Monaural Advantage - a pattern in which the sense for one ear is significantly greater than for both (greater than 20% difference is suggested).

Absolute Ear Difference - right ear score minus left ear score.

Adherence with Medication - the degree to which patients (clients) comply with recommended procedures for taking medicine.

Anomalies - marked deviations from normal.

Auditory Modality - the structures associated with reception and processing of information received by listening.

Basil Ganglia - a group of nuclei in the forebrain. Subcortical masses of gray matter in each cerebral hemisphere.

Corpus Callosum - fibers which connect the cerebral hemispheres.

DF - degrees of freedom.

FSIQ - Full Scale IQ - (WISC-R) - see PIQ.

Inter-rater Reliability - the degree of agreement among judges measuring the same event.

Level of Adherence - the degree to which patients (clients) comply with recommended (prescribed) treatment.

Mean Advantage (Mean Score) - the average of left, right, and binaural scores.

Non-Adherence - the degree of lack of compliance with prescribed treatment.

Non-Therapeutic Benefits - positive changes which cannot be directly related to the treatment.

Occluded Ear - the ear in which an earplug is worn.

P - probability value which assesses the likelihood that the observed difference in means is due to chance.

PIQ - Performance IQ - a measure of non verbal intellectual ability. Obtained through administration of Wechsler Intelligence Scale.

Positron Emission Tomography (PET) - a nuclear medicine imaging technique.

SD - Standard Deviation - a measure of spread or variability.

Therapeutic Benefit - positive change which appears to be directly related to the treatment.

T - (t-test) - a method of testing the statistical significance of the difference in two means.

Test-Retest Reliability - an estimation of reliability obtained by repeating the measurement procedure on the same set of subjects.

Usable - a term used to describe the ease of administration and interpretation of the ACT.

VIQ - Verbal IQ - (WISC-R) - see PIQ.

WISC-R - Wechsler Intelligence Scale for Children - Revised.

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STUDENT INTERVIEW FORM

Date: _____ **Name:** _____

Grade: _____ **School:** _____

1. For how many hours a day do you wear the earplug? _____ hours

2. Do you wear the earplug:
   - at school? Yes No
   - at home? Yes No
   - when playing sports? Yes No
   - when participating in extra curricular school or social activities? Yes No

3. Do you think there has been a change in:
   a) Your ability to do school work? Yes No
      If so, in what way? _____
      _____
   b) How do you get along with others? Yes No
      If so, in what way? _____
      _____
   c) How do feel about yourself? _____
      _____

4. How do you feel about wearing the earplug? _____
   _____

5. Have you had any problems with wearing the earplug? Yes No
   Comment _____
   _____

6. Did you stop wearing the earplug? Yes No
   If so, why? _____
   _____

PARENT/GUARDIAN INTERVIEW FORM

Permission Granted: _____

Date: _____

Person interviewed: _____

Relationship to child: _____

Child's name: _____

Grade: _____ **School:** _____

1. Does your child wear the earplug now? Yes No
2. For how many hours a day does he/she wear an earplug? _____ hours
3. When did he/she begin wearing the earplug? Mo _____ Yr _____
4. Do you think that he/she is helped by the earplug? Yes No

   If it does help, please describe how he/she is different when he/she is wearing the earplug.

   _____

   _____

   _____

   _____

5. Does the plug have any bad effects? Yes No

   If yes, please specify.

   _____

   _____

   _____

   _____

6. Do you think that, since wearing an earplug, his/her progress in school has:

   a) stayed the same Yes No
   b) improved Yes No
   c) got worse Yes No

7. Do you think that, since wearing an earplug, his/her behavior at home has:

   a) stayed the same Yes No
   b) improved Yes No
   c) got worse Yes No

8. Have any school staff told you whether they have noticed any change since he/she has worn an earplug? Yes No

9. Apart from the earplug, has he/she had any other treatment or extra help for learning problems? Yes No

   If yes, please specify.

   _____

   _____

   _____

   _____

   _____

10. Has he/she ever been tried on medication for learning problems? Yes No

    If yes, what medication? _____

    Did this medication help? Yes No

    If yes, how did it help?

    _____

    _____

    _____

11. Does he/she think that the earplug helps? Yes No

    If yes, what does he/she say that the earplug does?

    _____

    _____

    _____

    _____

    _____

12. Are there any other factors which may have contributed to this change? Yes No

If yes, please specify.

_____

_____

_____

_____

13. Has he/she discontinued wearing the earplug? Yes No

If yes, why?

_____

_____

_____

_____

INTERVIEW QUESTIONNAIRE (ACT USERS)

Name: _____

Position: _____

1. How often have you used the ACT?

2. For what purpose do you use the ACT?

3. Have you encountered any difficulties in administering and/or interpreting the ACT?

4. Do you have any general comments about the ACT (advantages, disadvantages, etc.).

5. Any "interesting" cases?

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